

CHAPTER EIGHT

Schottky Transistor- Transistor logic (STTL)

Digital Electronics.

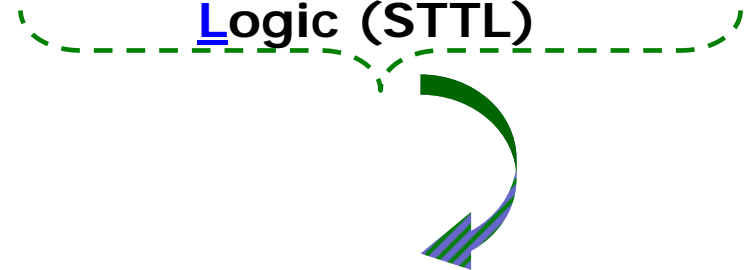
Introduction

Ch
8

Iransistor-Iransistor
Logic (TTL)



Schottky Iransistor-Iransistor
Logic (STTL)



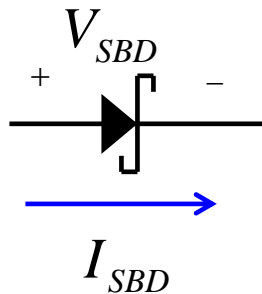
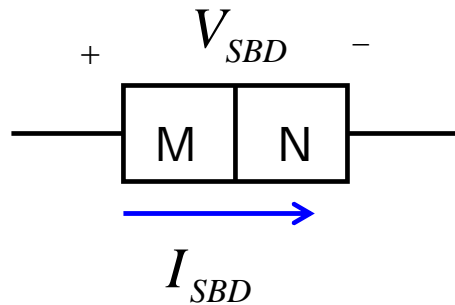
STTL is obtained by replacing the BJT with Schottky-clamped BJT (SBJT)

The primary advantage of SBJTs is their improved transient times since SBJT do NOT operate in saturation

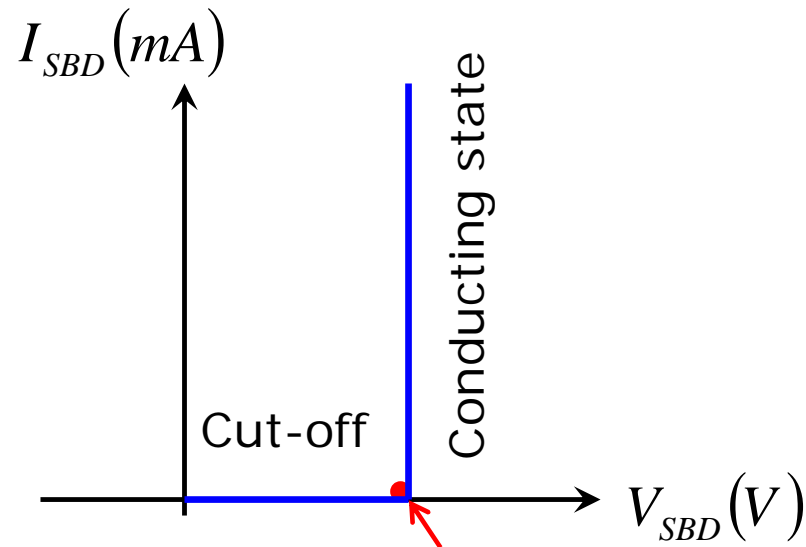
Schottky-Barrier Diodes (SBD)

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Schottky-barrier diode is made by adjoining **metal** and **N**-type semiconductor (usually aluminum with N-type silicon)



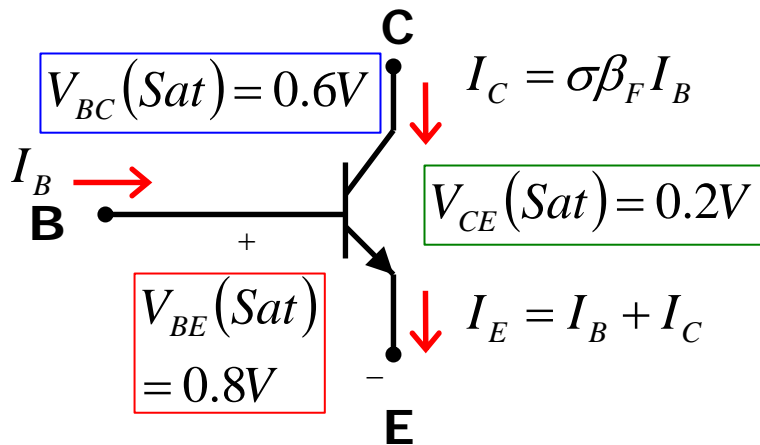
Circuit symbol



Current voltage characteristics

Schottky-Clamped SBJT

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Saturation Mode

A serious problem that limits the switching speed of a BJT inverter as well as the TTL gates is the time required to remove the enormous stored charge of the base of a saturated BJT.

Thus, the solution is to use BJTs that do not saturate.

The saturation can be avoided by limiting the forward-biased base-collector voltage to values less than 0.6 V

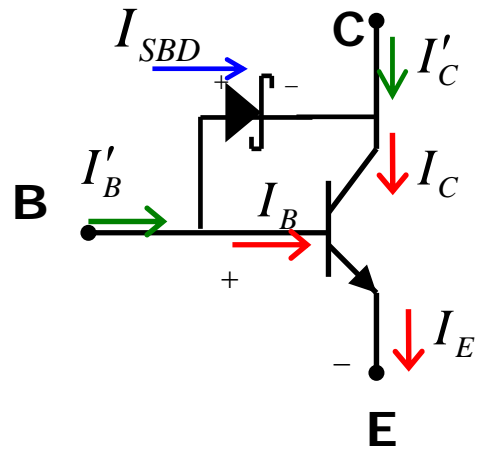
The saturation mode is characterized by the forward biased B-C voltage

$$V_{BC}(sat) = V_{BE}(sat) - V_{CE}(sat) \\ = 0.8 - 0.2 = 0.6V$$

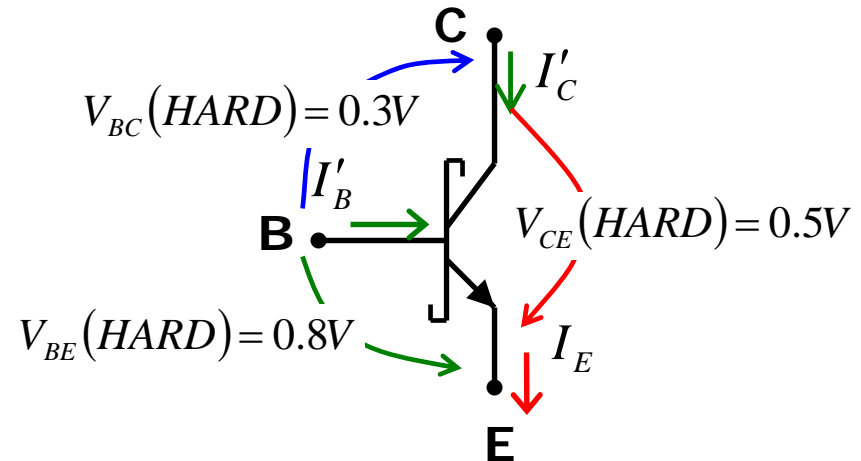
This is accomplished by placing SBD across the base and collector terminals of a BJT.

Schottky-Clamped SBJT

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Equivalent circuit



Circuit symbol

V_{BC} is limited to $V_{SBD}(ON) = V_{BC}(HARD) = 0.3V$

The 'ON-HARD' Mode:

1. BJT is F.A.
2. Schottky diode is conducting

The SBJT does not saturate $\Rightarrow \sigma = 1$

Schottky-Clamped SBJT

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"Inverse-active" Schottky Mode:

Since V_{BC} is limited to $V_{SBD}(ON) = V_{BC}(HARD) = 0.3V$
 $V_{BC}(RA) = 0.7V$

The SBJT can not operate in inverse active mode

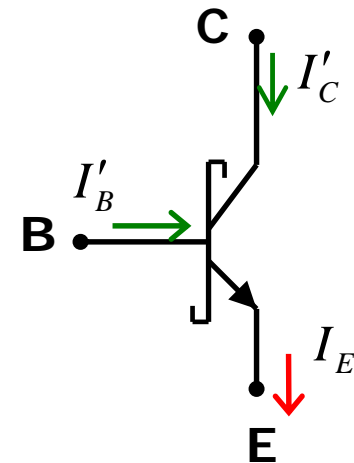
However, for

$$V_{BE} < V_{BE}(FA), V_{BC} = V_{BC}(RS) = 0.3V$$

$$I'_C = -I_{SBD}$$

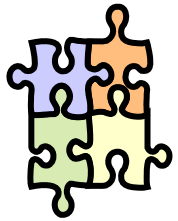
$$I'_B = I_{SBD}$$

$$I_B = I_C = I_E = 0$$



Schottky-Clamped SBJT

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Example

Determine the logic swing of SBJT shown, assuming

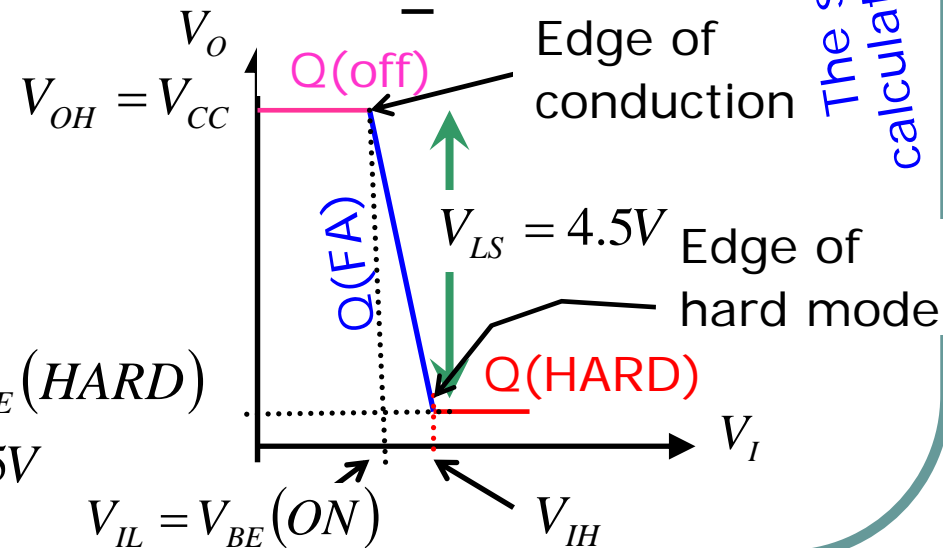
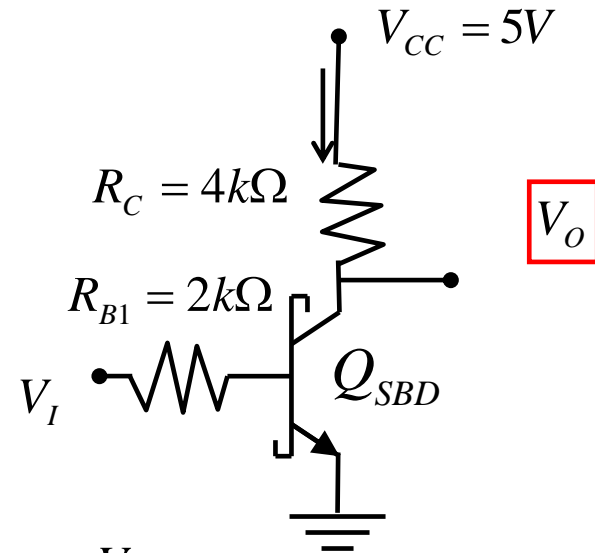
Solution

$\frac{V_{OH}}{I_{RC} = I_C = 0}$ When V_I is low, SBJT is cut-off
 $V_{OH} = V_{CC} = 5V$

$\frac{V_{OL}}{V_{OL} = V_{CE}(HARD) = 0.5V}$ → SBJT is "ON-HARD" mode,

Logic swing voltage =

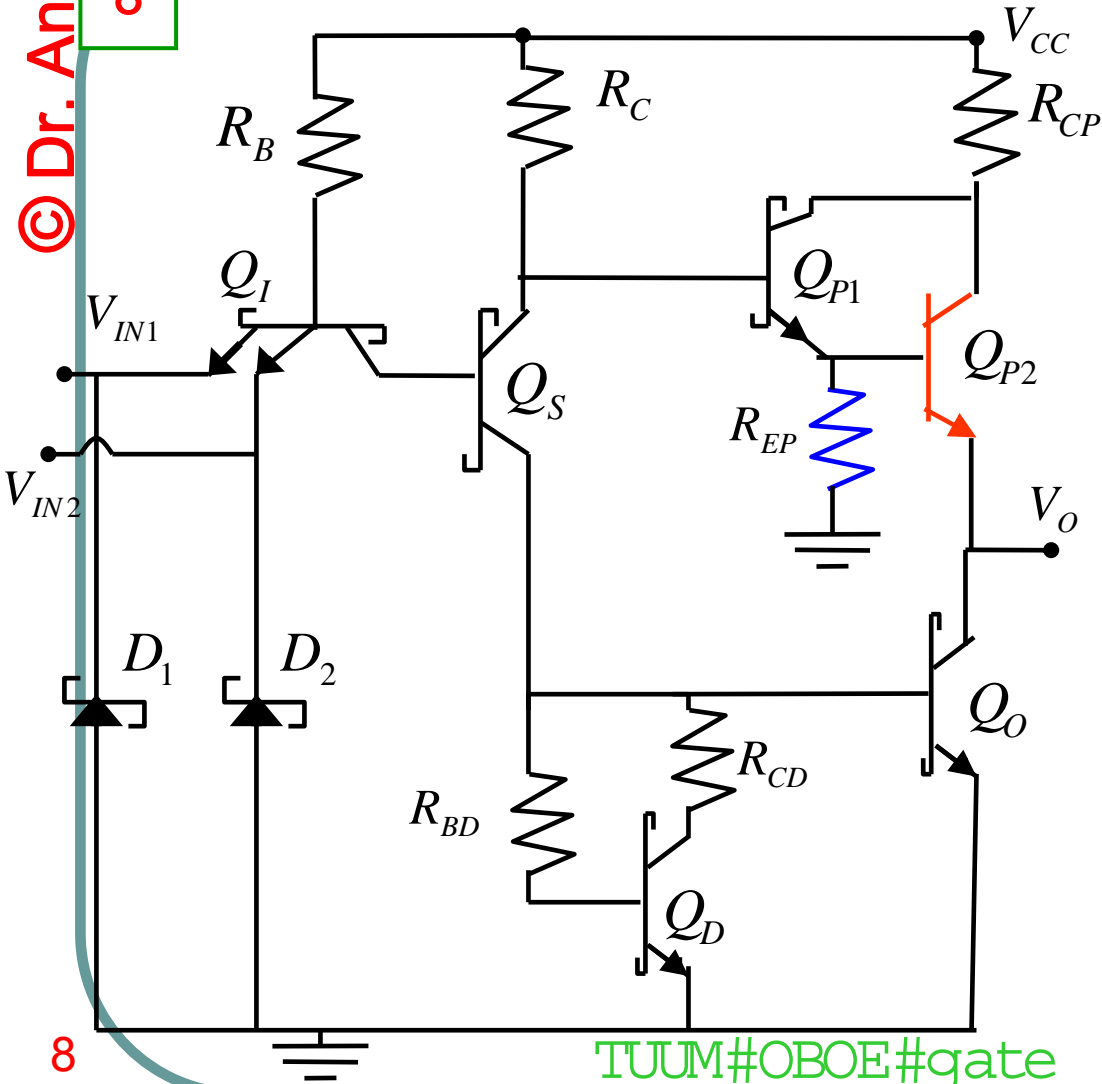
$$V_{LS} = V_{OH} - V_{OL} = 4.5V$$



The slope will be calculated in the class

(SSTTL) 54S00/74S00

Ch 8



- BJTs are replaced with SBJTs (except for Q_{P2})
- The Darlington pair (Q_{P1} & Q_{P2}) provides higher current to charge the load capacitance (Output low-high)
- Q_{P2} is a normal BJT because it can not saturate since

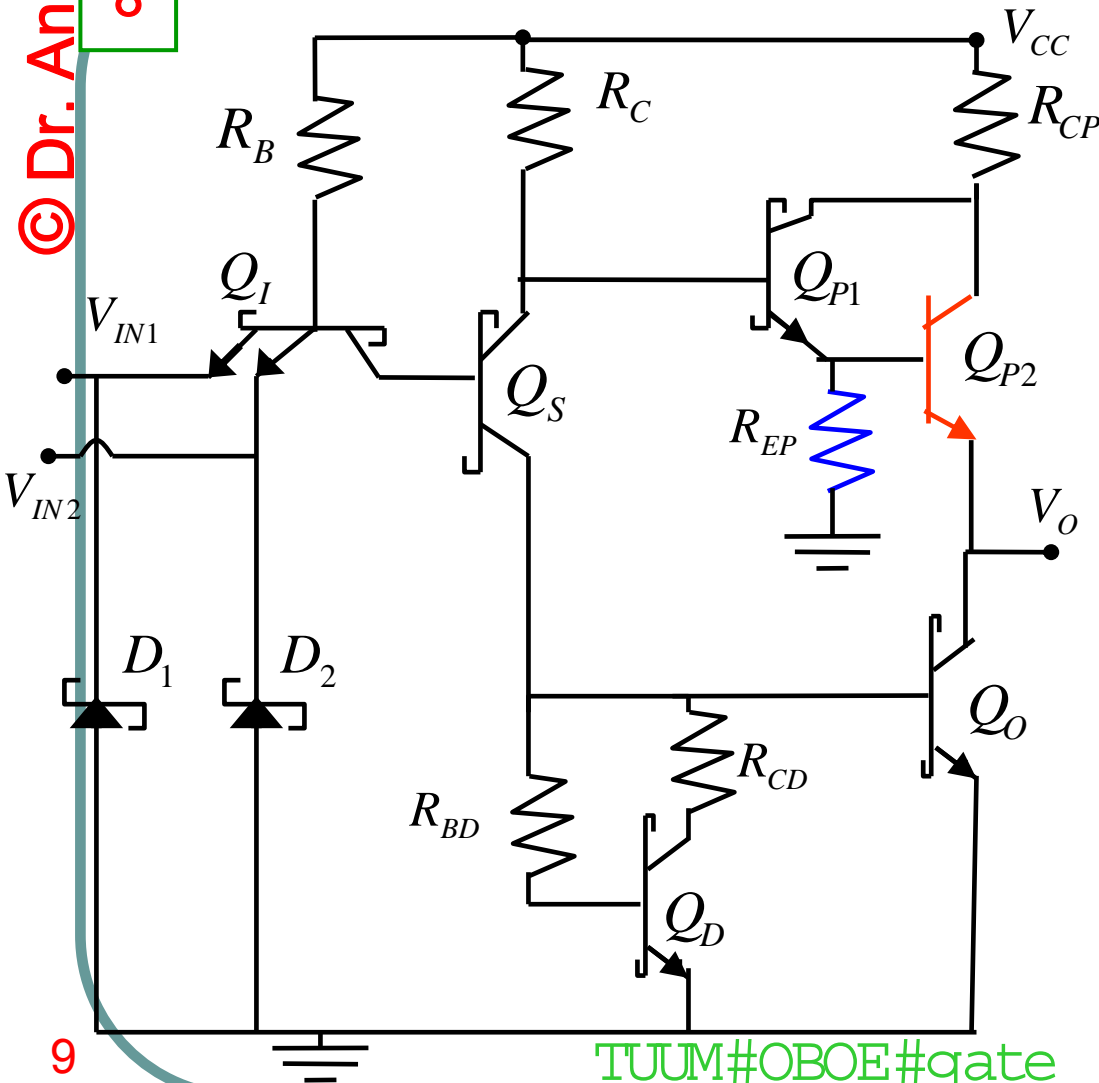
$$V_{CE,P2}(FA) = V_{CE,P1}(HARD) + V_{BE,P2}(FA)$$

$$V_{CE,P2}(FA) > V_{CE}(sat)$$

Schottky-Clamped TTL (SSTTL) 54S00/74S00

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Advantages of Q_D , R_{BD} , R_{CD} :

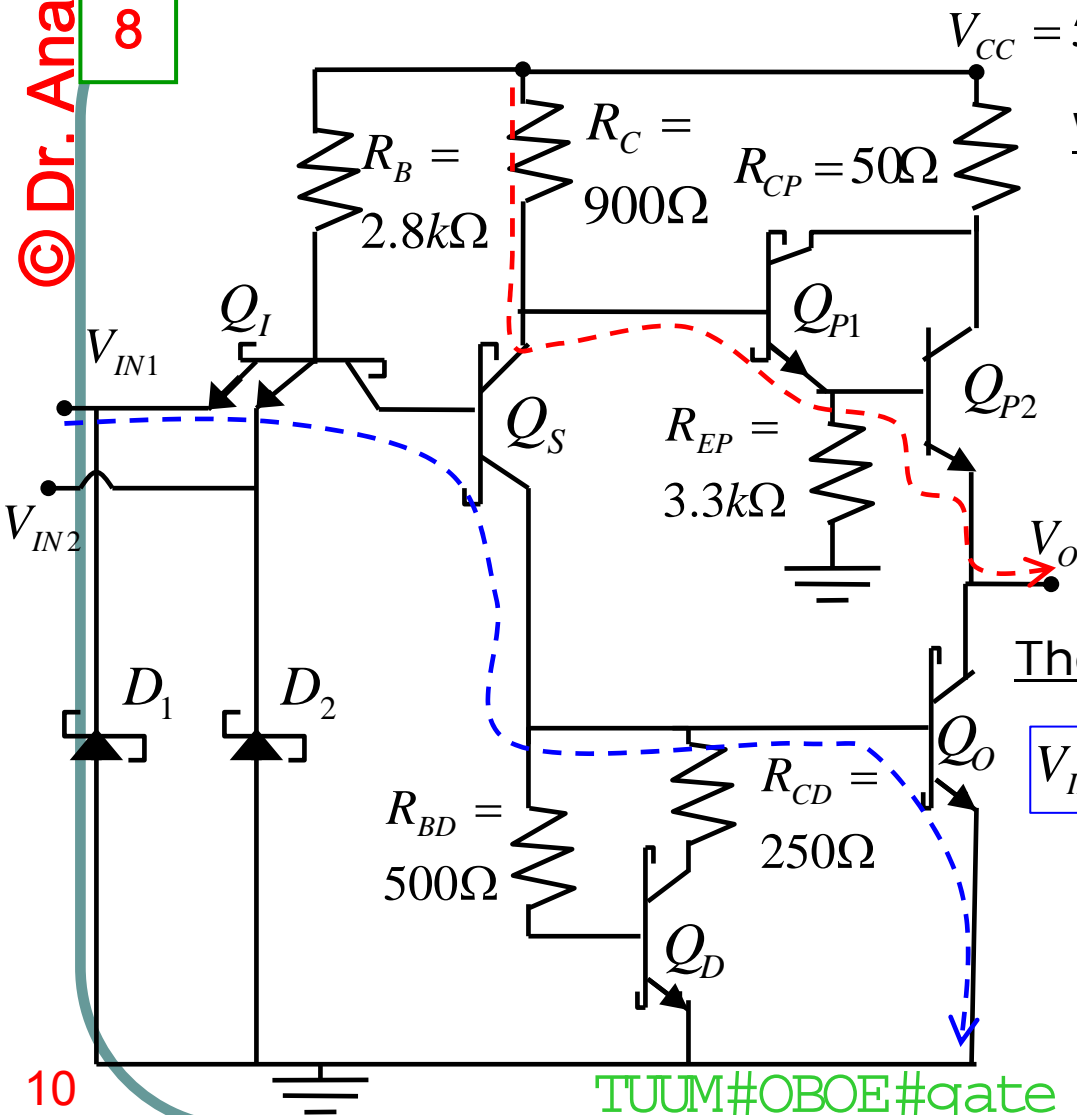
1. The break point between V_{OH} and V_{OL} is eliminated (Q_S , Q_O turn ON at the same time)
2. Narrower transition width and better noise margin
3. Discharge the base charge of Q_O during the low-high transition

R_B , R_C have smaller values than in TTL gates to increase the fan-out (but also increase $P_{CC}(avg)$)

VTC of SSTTI

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V_{OH}

When V_{IN} is low: Q_I is „Hard“.

Q_S , Q_D , and Q_O are off.

Q_{P1} and Q_{P2} are ON.

$$V_{OH} = V_{CC} - V_{BE,P1}(FA) - V_{BE,P2}(FA)$$

$$V_{OH} = 5 - 1.4 = 3.6V$$

(Neglecting I_{BP} .)

V_{IL}

The necessary voltage to turn Q_O ON

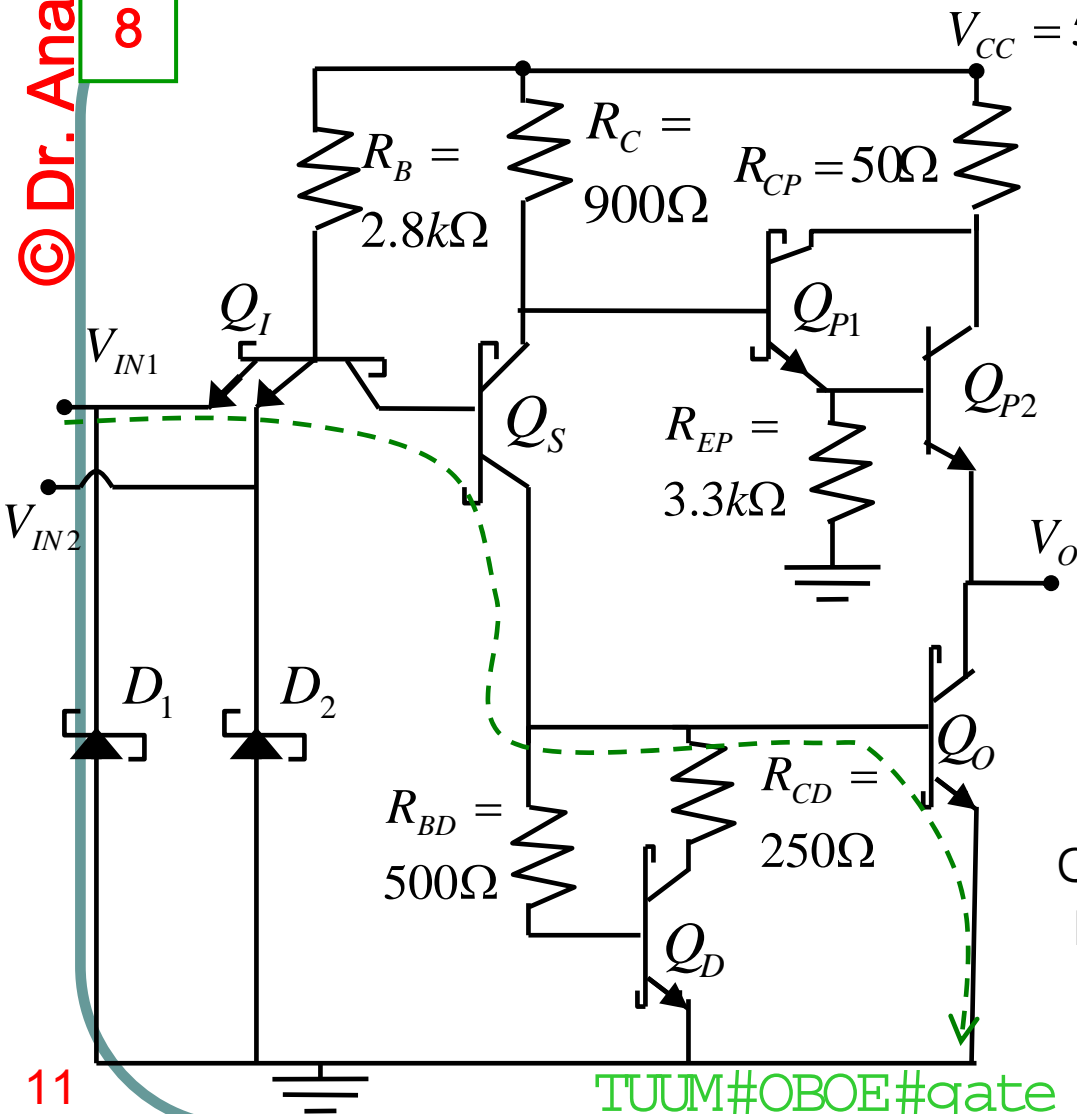
$$V_{IL} = -V_{CE}(HARD) + V_{BE,S}(FA) + V_{BE,O}(FA)$$

$$V_{IL} = -0.5 + 1.4 = 0.9V$$

VTC of SSTTI

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V_{IH} Q_S , and Q_O are in on-hard mode.

$$V_{IH} = -V_{CE}(HARD) + V_{BE,S}(HARD) + V_{BE,O}(HARD)$$

$$V_{IH} = -0.5 + 1.6 = 1.1V$$

V_{OL}

Q_O is SBJT

$$V_{OL} = V_{CE,O}(HARD) = 0.5V$$

$$V_{B,P1} = V_{CE,S}(HARD) + V_{BE,S}(HARD)$$

$$V_{B,P1} = 1.3 > 0.7V$$

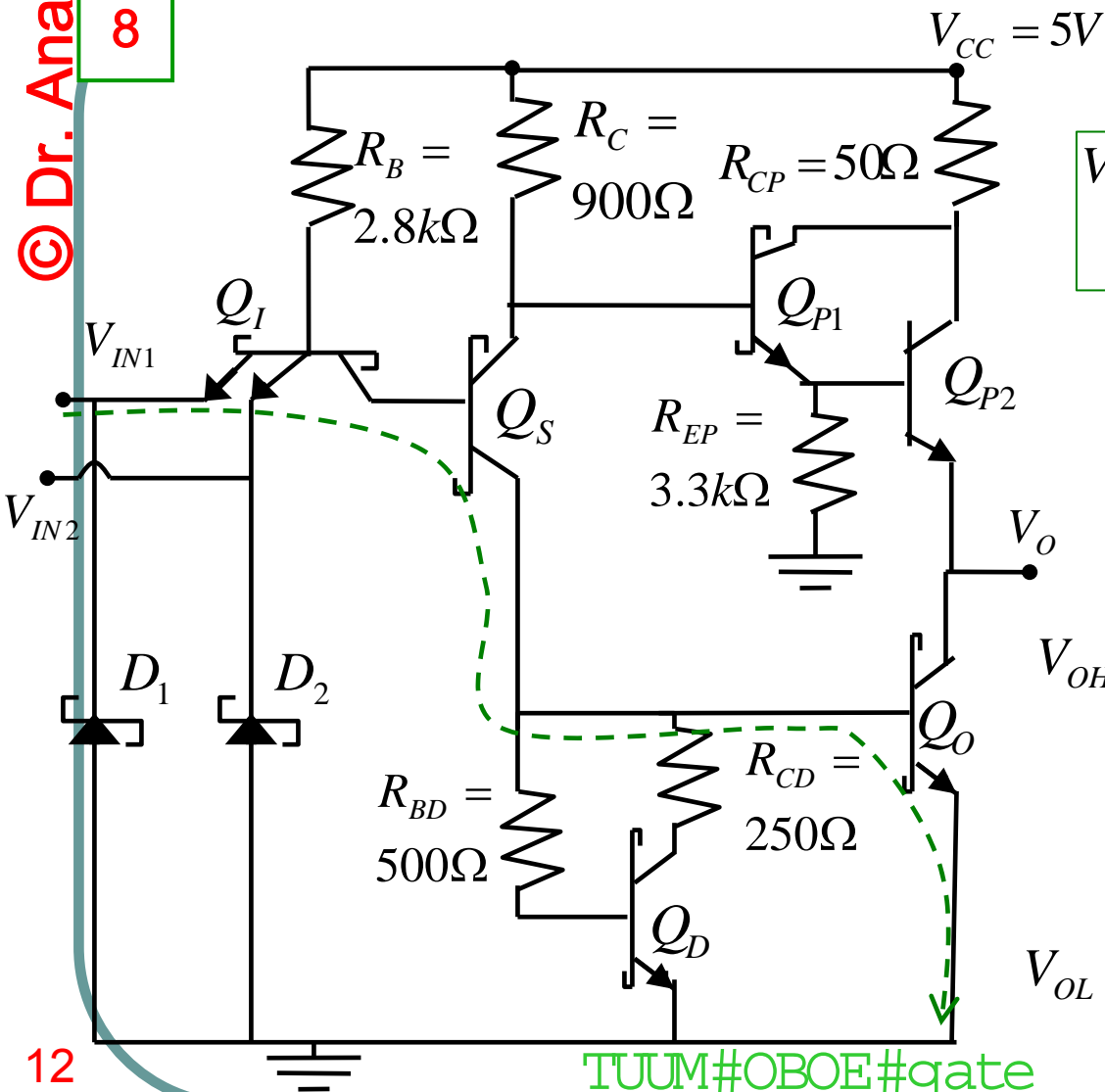
Q_{P1} is ON through R_{EP}
but Q_{P2} is OFF

$$(V_{BE,P2} = 1.3 - 0.7 - 0.5 = 0.1V < V_{BE}(FA))$$

VTC of SSTTI

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V_{IH}

Q_S , and Q_O are in on-hard mode.

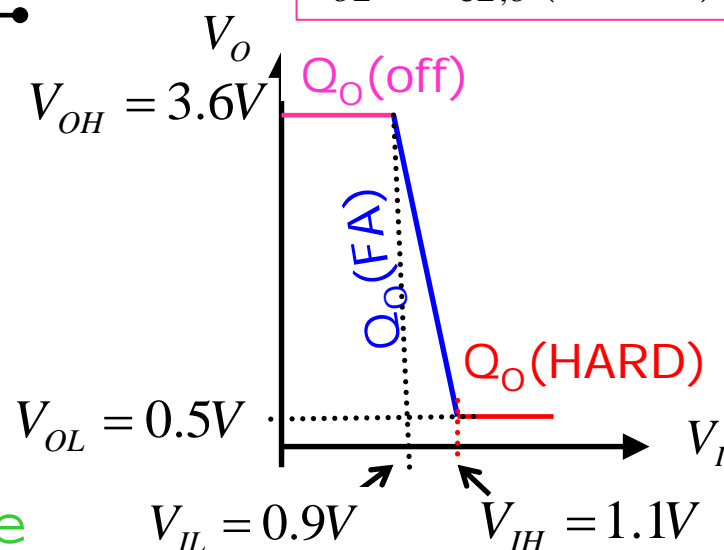
$$V_{IH} = -V_{CE}(HARD) + V_{BE,S}(HARD) + V_{BE,O}(HARD)$$

$$V_{IH} = -0.5 + 1.6 = 1.1V$$

V_{OL}

Q_O is SBJT

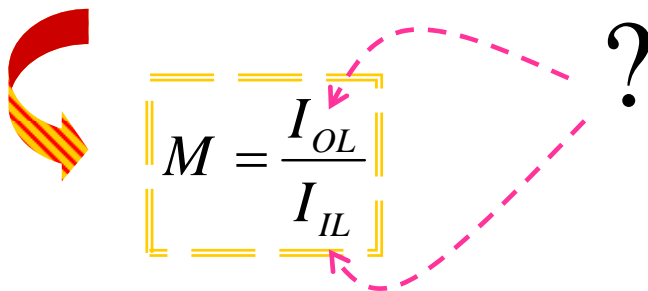
$$V_{OL} = V_{CE,O}(HARD) = 0.5V$$



STTL Fan-Out

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8

When the output is high, I_{IL} is negligible.
Therefore, Fan-out depends on the output low state

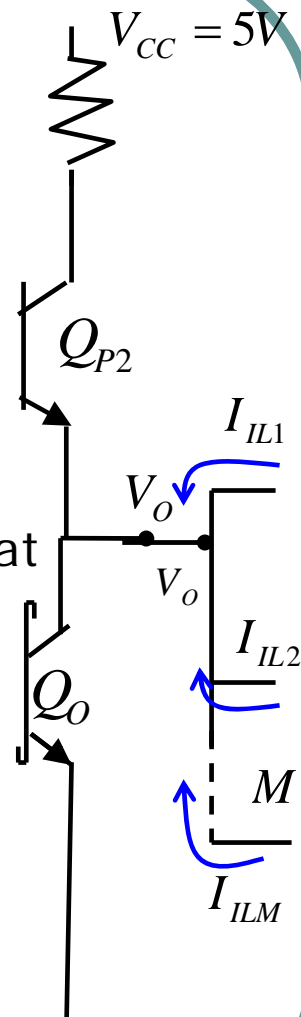


$$M = \frac{I_{OL}}{I_{IL}}$$

Input current low I_{IL}

For the input low state, Q_I is sat and Q_S is cut-off

$$I_{IL} = I_{EI} = I_{RB} = \frac{V'_{CC} - V'_{BE,I}(HARD) - V_{CE,O}(HARD)}{R'_B}$$



STTI Fan-Out

Ch
8

Output current low I_{OL}

$$I_{OL} = I_{C,o}(HARD)$$

Since the output Q_{P2} is cut-off

$$I_{OL} = \beta_F I_{BO}$$

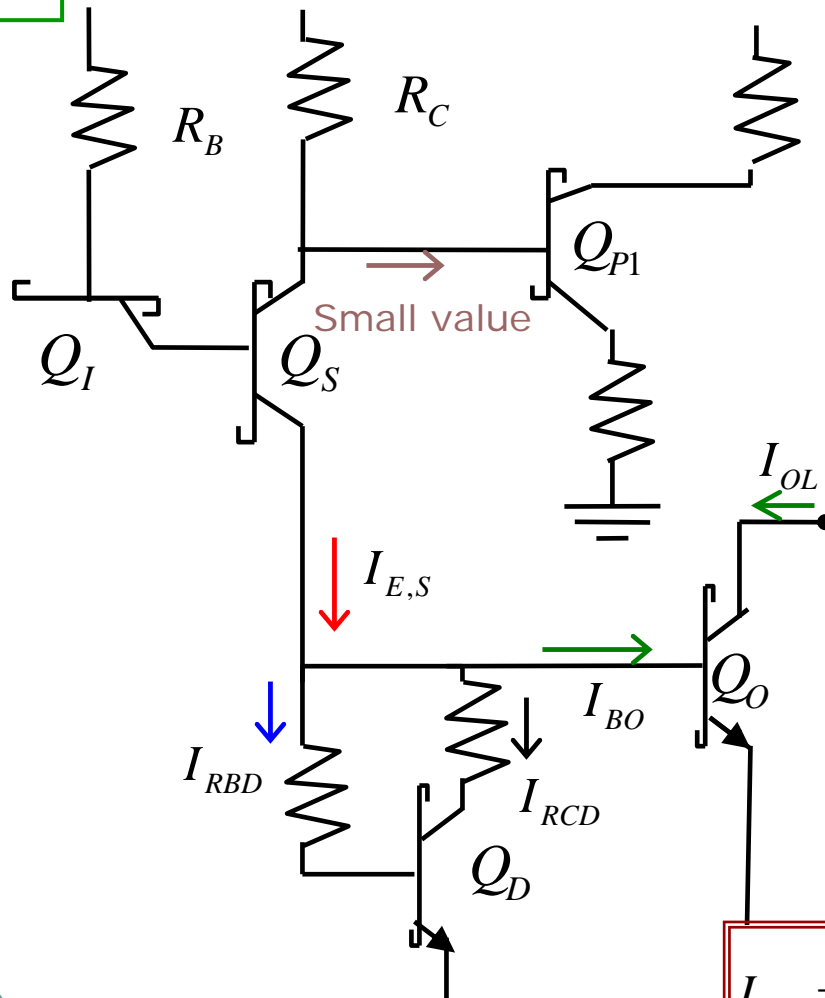
$$I_{BO} = I_{E,S} - (\cancel{I_{RBD}} + I_{RCD}) \quad \text{Negligible}$$

$$I_{RCD} = \frac{V_{BE,O}(HARD) - V_{CE,D}(HARD)}{R_{CD}}$$

$$I_{E,S} = I_{B,S} + I_{C,S}$$

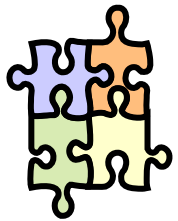
$$I_{C,S} = \frac{V_{CC} - V_{CE,S}(HARD) - V_{BE,O}(HARD)}{R_C}$$

$$I_{B,S} = \frac{V_{CC} - V_{BC,I}(HARD) - V_{BE,S}(HARD) - V_{BE,O}(HARD)}{R_B}$$



STTL Fan-Out

Ch
8



Example

Determine the maximum fan-out of the SBJT circuit shown, assuming $\beta_F = 49$

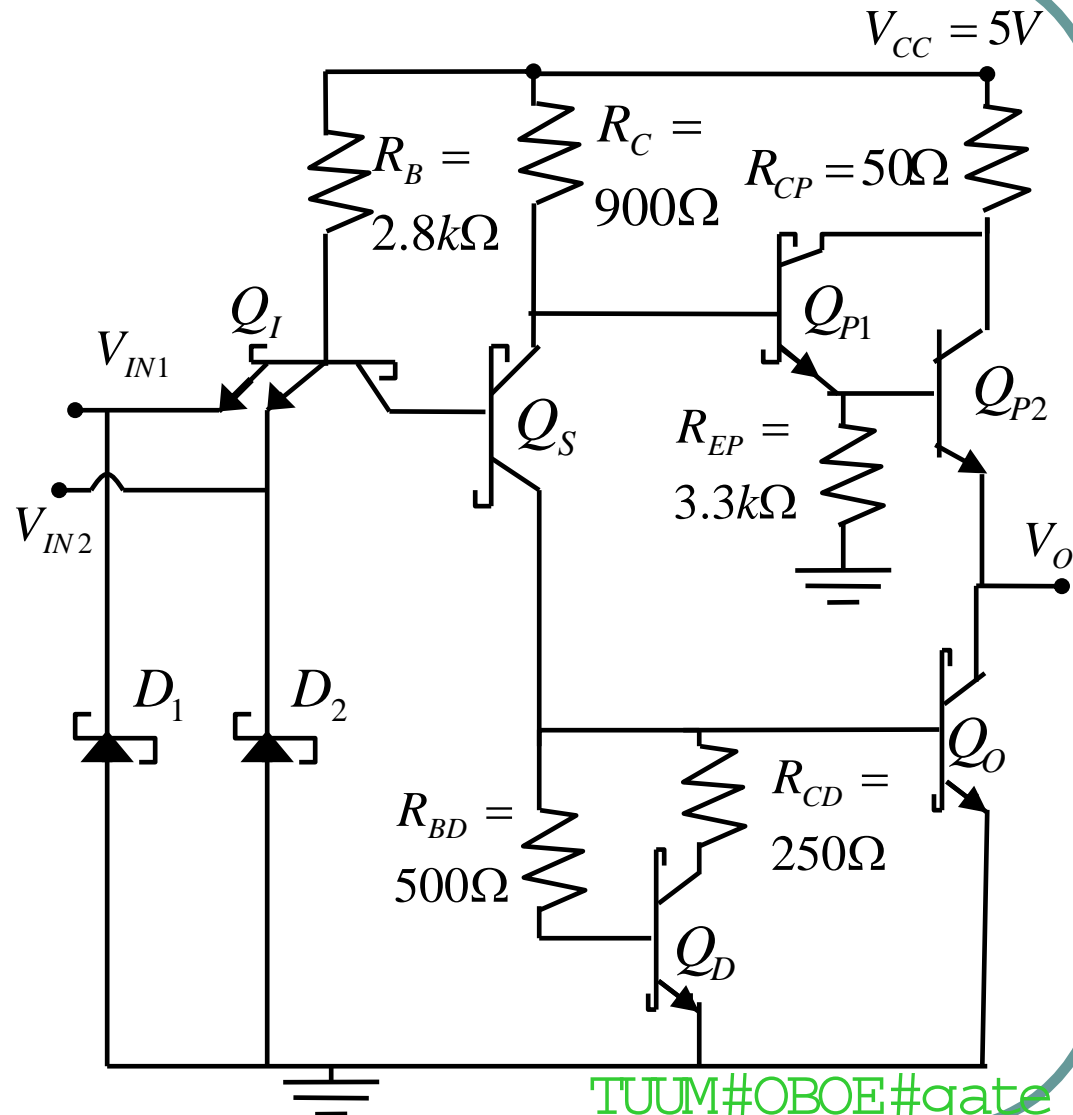
Solution

$$I_{IL} = \frac{5 - 0.8 - 0.5}{2.8k} = 1.32mA$$

$$I_{RCD} = 1.2mA \quad I_{B,S} = 1.11mA$$

$$I_{C,S} = 4.11mA$$

$$M = 149$$



- HW #8: Solve Problems: 8.1 , 8.3, 8.8,
and 8.19